- Explain the princip[...] CT scan and MRI.

Introduction

All animals show some common characteristics, one of these is to produce response to **stimuli** (*i.e.* any internal and external change). The activities of different body parts in response to the stimuli must be **coordinated**. The coordination makes possible the integration of functions essential to animal behavior. It is must for animals and human to survive. In human and most animals there are two types of coordination, *i.e.* nervous coordination and endocrine coordination. This unit deals with only nervous coordination.

17.1 Nervous System of Man

The study of nervous system is known as **neurology**. The working of different body parts with cooperation to each other and under the control of coordinator (Brain, Spinal cord or ganglia) is called **coordination.**

The system of the body that provides coordination through electric signal among different body parts during the response to a particular stimulus is called **nervous system**. The most developed, advanced and evolved nervous system among all organisms is that of human.

17.1.1 Steps Involved in Nervous Coordination

Nervous coordination involves highly specialized cells known as **neurons**, which are either connected together or via centralized nervous system to form a network that is linked to the receptors and effectors.

Nervous system in human and higher animals consists of three basic elements.

- **Receptors** are cells, tissues or organs which receive stimuli and give information to sensory neurons.
- **The neuron** has the capacity to generate and conduct impulses to central nervous system where processing / analysis of information takes place and pass responses to the effectors.
- **Effectors** are structures such as cells, tissues, muscles and glands which carry out action or make responses.

17.1.2 Receptors or Transducers

Receptors are organs, tissues, cells or nerve endings that detect changes (stimuli) in the external or internal environment of an animal (*e.g.* Human). These stimuli then transmitted to the brain or spinal cord through sensory neurons.

Classification of Receptors on the Basis of Stimuli

Receptors are classified into following five types.

- **Chemoreceptors,** which detect the concentration of certain chemicals or ions, *e.g.* CO_2 level in the blood by **medulla of brain**, O_2 level by **carotid body**. The chemoreceptors for blood glucose, amino acids, fatty acids are located in the **hypothalamus of brain**, smell **(olfaction)** in the nasal epithelium, taste **(gustation)** found in tongue and osmoreceptor (detect osmotic pressure of blood) in hypothalamus.
- **Mechanoreceptors,** which detect stimuli of pressure, body position or acceleration, include **Meissner's corpuscles** in skin for touch, **Pacinian's corpuscles** also in skin, **baroreceptors** in blood vessel for pressure and stretch also in, **ear** for hearing and equilibrium.
- **Thermoreceptors** are mostly located in the skin to detect change in temperature (cold/warmth).
- **Nociceptors** are pain receptors widely distributed in the skin and other internal organs which detect damage to body tissues.
- **Photoreceptors** or **electromagnetic receptors,** detect light stimuli, such as rods and cone cells in the retina of our eyes.

17.1.3 Processing / Analysis of Information

All types of sensory inputs from various receptors are conveyed to coordinator *i.e.* brain and spinal cord by sensory neurons. The information collected by them is processed and analysed, for a suitable response by special types of neurons known as inter or associated or relay neurons.

17.1.4 Effectors

Effectors respond to stimuli by impulse coming via motor neuron, such as

muscles and glands. The glands secrete some types of chemicals while muscles respond by contracting.

Stimulus Receptor Sensory neuron Inter neuron (CNS) Motor neuron Effector Response.

17.2 Neurons

Neurons are the chief structural and functional units of nervous system. In addition to neurons, nervous system contains neuroglial cells, which nourish the neurons and also protect the neurons by myelin sheath.

17.2.1 Structure of Neuron

A typical neuron consists of three basic components, *i.e.* cell body, axon and dendrites. The **cell body** or **soma or cyton or perikaryon of neuron** contain, nucleus and various cellular organelles except centrioles. The neuron cell body contains a mass of granular cytoplasm and enclosed by cell membrane (neurilemma). The nucleus is centrally placed. The cell body contains a group of ribosomes associated with rough endoplasmic reticulum and Golgi bodies known as **Nissl's granules** (these help in protein synthesis and acetyl-choline forming enzyme) These granules are absent in axon and Dendron. (Fig.17.1)

Interesting Information

Nervous system also cont-ains about 50% of neuro-glial cells.

The cell body of neuron is surrounded by cytoplasmic fibres, which are of two main types, *i.e.* axon and dendrites.

Axons are cytoplasmic process that conduct impulses away from cell body. Each axon is a usually thick long fibre (few mms to more than a meter in length) with a constant diameter. The cytoplasm of the axon is called **axoplasm** and cell membrane is called **axolemma**. Each axon terminates by branching to form small extension with knob like ending to cell presynaptic terminal. The neuroglia or glial cells that nourish, protect and support the neurons. In peripheral nervous system these cells are known as **Schwann cells**, which cover the axon by repeatedly wrapping it.

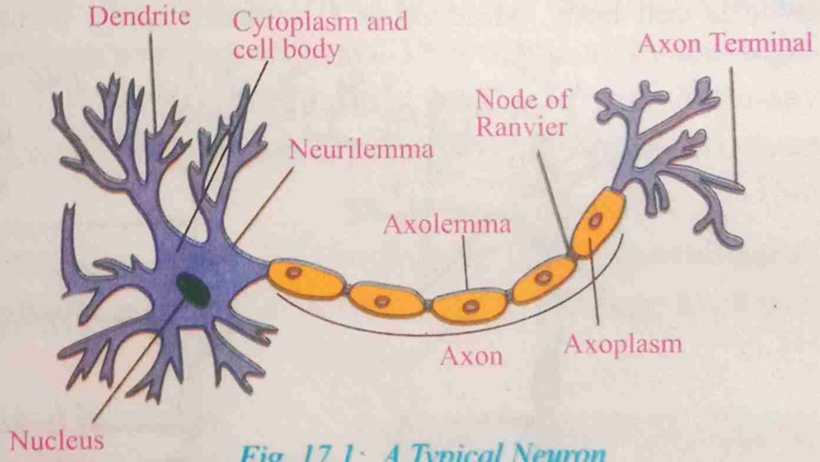


Fig. 17.1: A Typical Neuron

These cells are also covered by a fatty substance known as **myelin sheath**, which act as an insulator. Thus axons are called **myelinated fibres**. The non-myelinated portion of axon is called **node of Ranvier,** located between Schwann cells. The impulses jump from node of Ranvier to node of Ranvier, which are known as **saltatory impulses**.

> **Myelinated Fibres**
>
> It is transmit impulses much rapidly than non-myelinated neuron. It has larger and thicker axon because velocity of impulse depends upon the diameter, length and myelin sheath.

Dendrites are also cytoplasmic extensions that carry impulses towards the cell body. If they are single, then called **Dendron**. They are thin, short and mostly branched. The branches are gradually tapered from the base to their tips. The gap between dendrites of one neuron and axon terminals of another neuron is called **synapse**.

17.2.2 Types of Neurons

On the basis of functions, the neurons are of three types, *i.e.* sensory neurons, inter neurons and motor neurons.

i) **Sensory Neurons** conduct impulses form receptors to central nervous system. These are **unipolar** because only one fibre **originating** from cell body which immediately gives rise to two branches, one towards receptor and other towards central nervous system. Both fibres are structurally axon like except their terminal portions differ that is one is like dendrites and other is like axon. One (axon) carries impulse towards cell body while other (Dendron) away from cell body. Majority of sensory

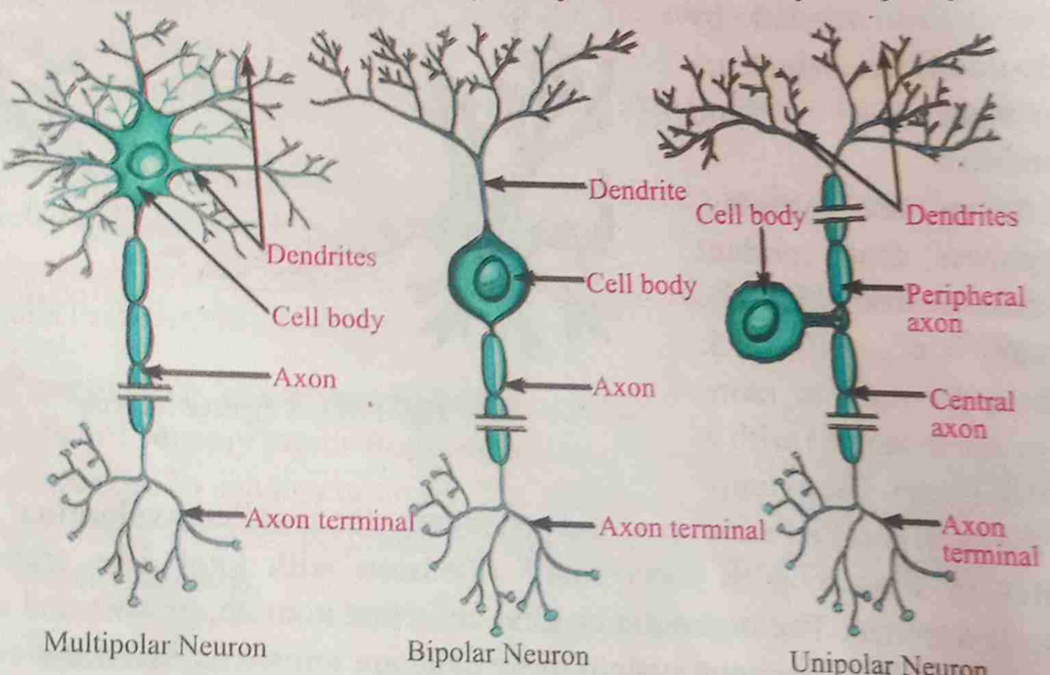


Fig.17.2: Multipolar, Bipolar and Unipolar Neurons

neuron are unipolar but some are bipolar. The unipolar neurons are found specially in dorsal root of spinal cord. (Fig.17.2)

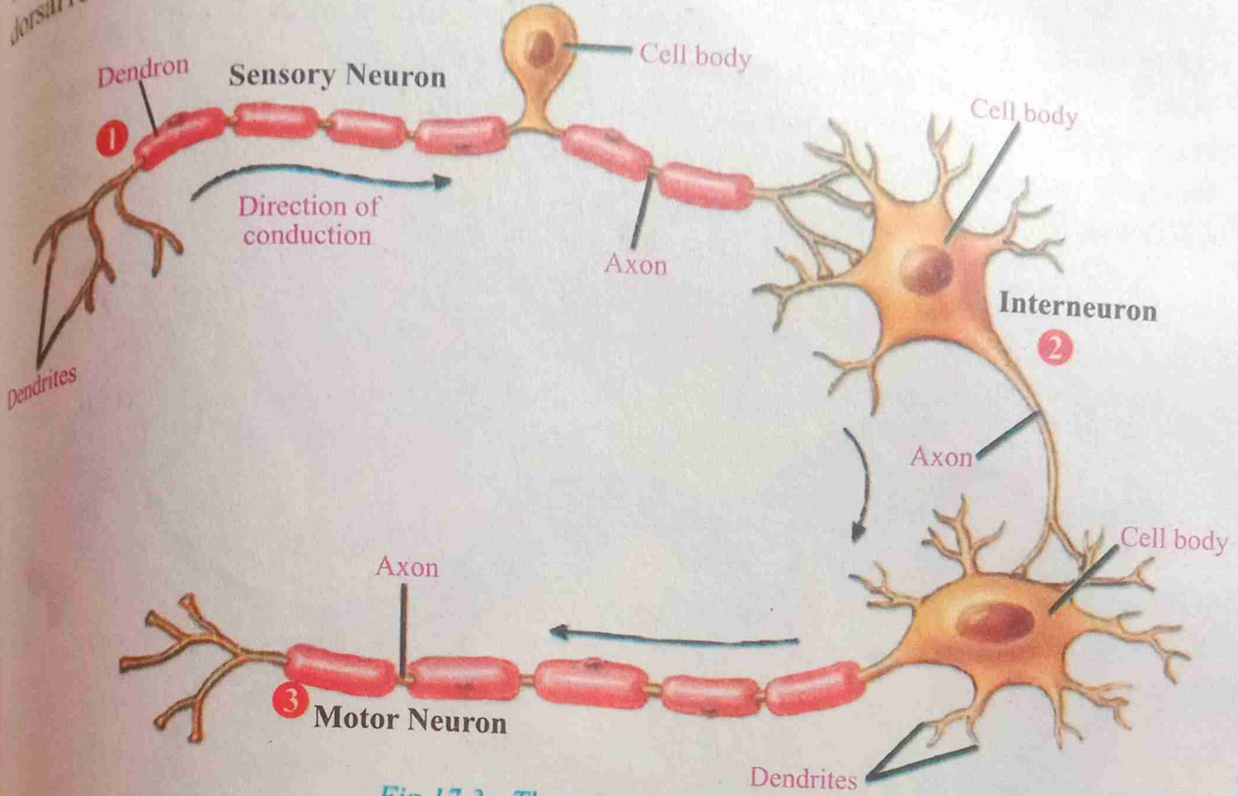


Fig.17.3: Three types of Neurons

ii) **Associated or Interneurons** are found only in the brain and spinal cord. These conduct impulses from sensory neurons to motor neurons. They also convey messages between various parts of the CNS. Inter neurons are mostly **multipolar** because many fibres arises from cell body. Their axon is thin and non-myelinated, while many dendrites carry impulses to its cell body.

iii) **Motor Neurons** conduct impulses from CNS to effectors. These are **multipolar** neurons. Their cell body contains many branched dendrites and a single long axon runs towards effector. (Fig.17.3)

Myelinated and Non-Myelinated Neurons

Myelinated neurons (Nerve fibres) are covered by fatty layer known as myelin sheath (axons) whereas non-myelinated neurons do not have a myelin sheath (Dendrites and Cell bodies). In myelinated neurons conduction of impulses are faster than non-myelinated neurons. Inter neurons are non-myelinated while motor and sensory neuron have myelinated portion.

Myelinated Neurons

The impulse jump from node of Ranvier to node of Ranvier. This is called saltatory impulse. Nerve impulse is 20 times faster in myelinated neuron than non-myelinated neuron.

17.2.3 Reflex action and Reflex arc

Reflex action or Reflexes are involuntary, automatic, unconscious or immediate response to external or internal environmental change or stimuli. The pathway through which a reflex travel is called **reflex arc**. The direction of reflex action is from receptor to sensory neuron to CNS to inter neuron and then through motor neuron to the effectors. Reflexes have no involvement of conscious portion of brain, therefore, the response is quick than the conscious pathway. (Fig.17.4)

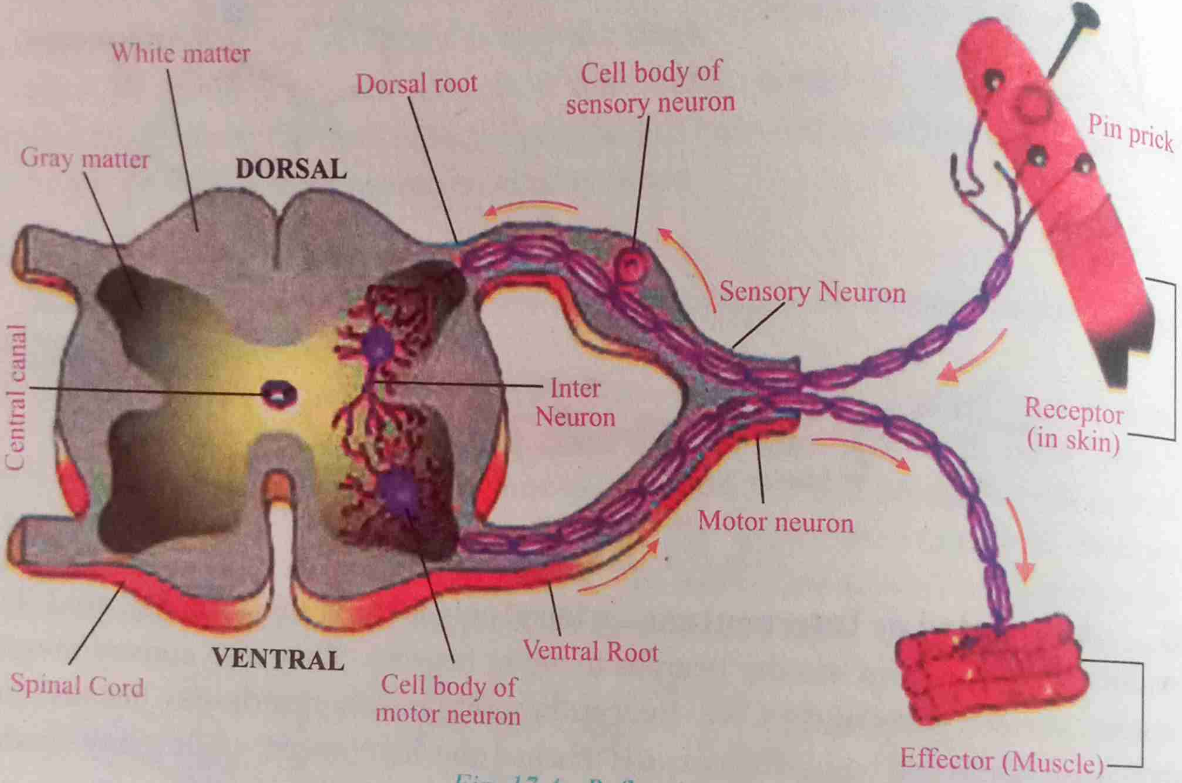


Fig. 17.4: Reflex Arc

Example of Reflex arc: If we unexpectedly touch a hot object or pin prick, our hands are rapidly removed from it. The receptors of our hands are activated by heat of the object. This impulse is conveyed to sensory neuron leading to spinal cord via spinal nerve then to inter neuron which lies entirely within the spinal cord. The inter neuron then passes this impulse to motor neuron then to effectors, *i.e.* muscles which causes them to contract. (Fig.17.4)

17.3 Nerve Impulse

Nerve impulse is the information about a stimulus that is transmitted from receptors to CNS and from CNS to the effectors. It is a wave of electrochemical change which runs along the length of the neuron,

> **Extra Information**
>
> Refractory period lasts for about four millise-conds so as a neuron can conduct 250 impulses per second.

involving chemical reactions and movement of ions across the **neurilemma**. The measurement of the capacity to do electrical work is known as **electric potential**. It represents a type of stored energy produces during separation of charge through a barrier. The charges are positive or negative, which act as separating barrier in the plasma membrane of neuron (Neurilemma).

Oscilloscope

It is an instrument with a screen which display changes in the voltage on both side of plasma membrane of neuron with time. The electric potential which exists across a cell membrane is known as **membrane potential**. The membrane potential is either resting membrane potential (RMP) or action membrane potential (AMP).

> **Extra Information**
> In human, normally the speed of flow of impulse in neuron is about 100-120m/ second.

17.3.1 Resting Membrane Potential

A typical neuron at rest or non-conducting neuron is called resting membrane potential. In this case a typical neuron is more positive electrically outside than inside the plasma membrane while inside is more negative as compared to outside the plasma membrane. It measures about **– 70 millivolts (- 0.07 volt)**.

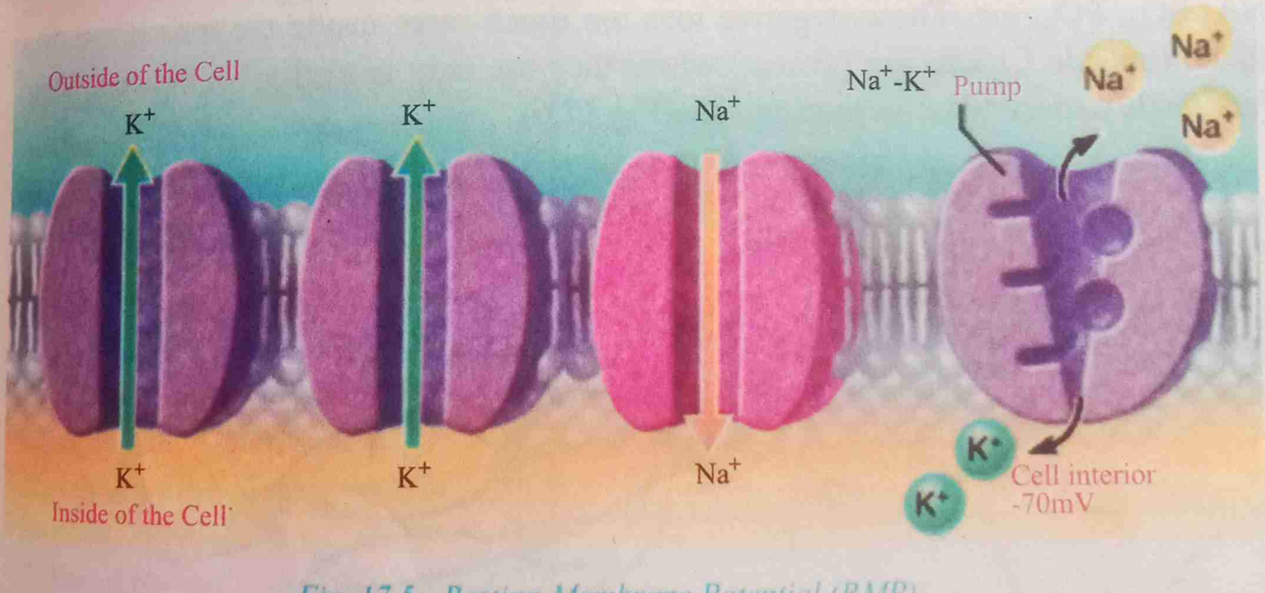


Fig. 17.5: Resting Membrane Potential (RMP)

Factors Involved in Resting Membrane Potential (RMP)

Major factors that are involved in RMP are:

Sodium and Potassium ions

There are many kinds of ions which are present inside and outside the plasma

membrane of neurons but the most important is sodium (Na^+) and potassium (K^+) ions. Sodium ions are tenfold higher in concentration outside than inside the membrane, whereas potassium ions are thirty fold higher in concentration inside than outside the membrane. The membrane of all the nerve cells possesses sodium and potassium pumps to transport these ions with the help of energy (ATP) against their concentration gradients. For every two potassium that are actively transported inside the membrane, three sodium ions are pumped out. Thus inside become more negative (70 mV) than the outside of the plasma membrane of nerve cell, which is more positive electrically than inside the membrane.

Table 17.1: Ionic Concentration Inside and Outside of Resting Neuron

Ingredients	Concentration (mmol/L)	
	Inside	Outside
Sodium ions	15	145
Potassium ions	150	5
Negative ions	156	30

Negative Organic Ions

Many types of large negative organic compounds are present in the both sides of plasma membrane of neurons. These organic ions include some proteins, amino acids, RNA, SO_4, PO_4, *etc*. These negative ions are much more inside the membrane than outside (outside Cl ions are present) where they are only in negligible concentration. Thus inside is more negative than outside.(Fig.17.6)

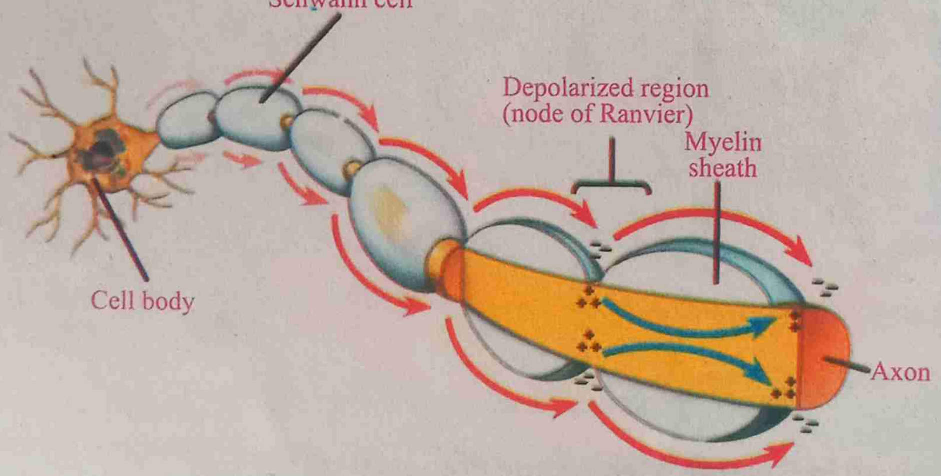


Fig. 17.6: Depolarized Region and Saltatory Impulse

Channel Proteins (Gates) in Plasma Membrane of Neurons

The plasma membrane is virtually impermeable to all ions except potassium ions.

It is slightly permeable to potassium, so it leaks out of the neuron by diffusion. That is why inside becomes more negative than outside of the plasma membrane of neuron. Thus non-conducting neuron is in **polarized state** (*i.e.* RMP – 0.07 volts or 70 mV). The resting membrane potential (RMP) will be maintained in undisturbed membrane. If it is disturbed or stimulated by a sufficient stimulus known as **threshold,** then action potential will occur.

17.3.2 Action Membrane Potential (AMP) (Depolarized State)

In action/active membrane potential, inside of neuron become more positive and outside become more negative. It is called depolarized state, which happen when appropriate stimulus receives, the positive charge sodium ion tends to move inside of the neuron. The electrochemical change is so brief (about one millisecond) that only a portion of the neuron (*i.e.* one node of Ranvier to another node of Ranvier) is in the action membrane potential state followed by the recovery of polarized state, thus impulses flow from one node of Ranvier another to node of Ranvier.

The major factors involved in changing the resting membrane potential to action membrane potential are:

1. **Threshold Stimulus**

It is capability of a stimulus to bring electrochemical charge on neuron or to excite a given tissue. It is also known as **adequate stimulus** (about – 50 to -55 mV electric membrane potential). If stimulus is not capable to excite or not appropriate, then it is called sub **threshold or inadequate stimulus**.

Influx of Na^+ ions

When threshold is reached, the membrane become more permeable to Na^+ than to the K^+ due to the opening of Na^+ gates. Thus influx of Na^+ ions by diffusion occurs, and electric potential of the membrane changes from -70 mV towards zero and then reach to about 50mV. This reversal of polarity

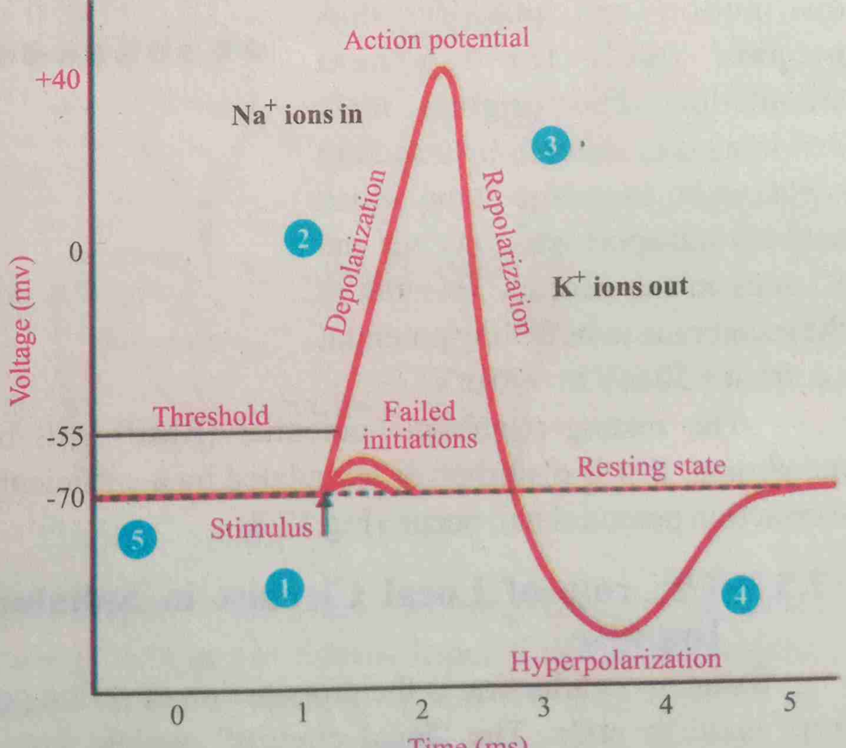


Fig. 17.7: Flow of Impulse

across two sides of membrane is called **depolarization**. This state of electropositive inside and electronegative outside lasts for about one millisecond till the Na^+ gates are not closed.

> ***Interesting Information***
>
> The continuous impulse occurs in non-myelinated neuron fibres in which K^+ and Na^+ ions can move across the memb-rane along the length of neuron so action poten-tial flow as a wave.

Repolarized state

After the peak of action potential, called the **spike potential**, the permeability of Na^+ decreases, and now become more permeable for K^+ by opening of K^+ gates thus K^+ rapidly diffuses out from cytoplasm to extracellular fluid. The sodium gate closes and the neuron get its original polarity *i.e.* **repolarized** (inside more electro negative and outside more electro positive). Infact, there is a slight overshoot into a more negative potential than original resting potential. This is known as **hyperpolarized** state. It is due to the slight delay in closing of all K^+ gates compared with Na^+ gates. (Fig.17.7)

Refractory Period (Resting State)

It is a period when after an action potential, nerve fibre undergoes a period of recovery, in which it regain the original ionic distribution and polarity, thus prepare itself for the next stimulation. The original ionic distribution is restored by a sodium – potassium exchange pump which actively transport Na^+ ions out and K^+ ions in the neuron. This return the membrane to its resting potential *i.e.* from +50 mV to –70 mV.

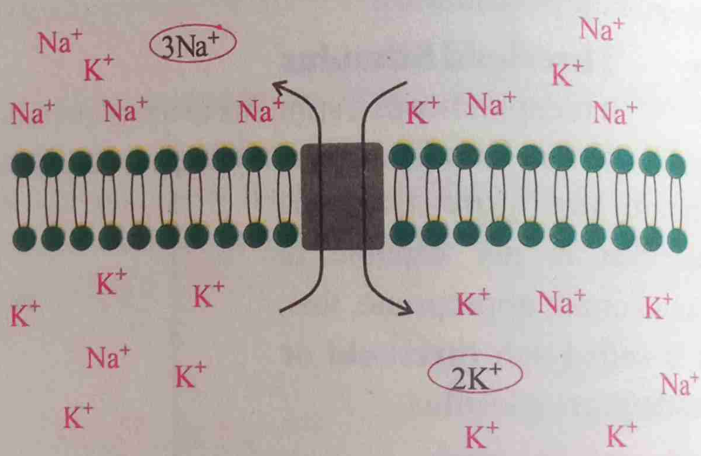


Fig. 17.8: Refractory Period of Neuron

The resting membrane potential (RMP) will be maintained in undisturbed membrane. If it is disturbed or stimulated by a sufficient stimulus known as threshold, then action potential will occur. (Fig.17.8)

17.3.3 The role of Local Circuits in Saltatory Conduction of Nerve Impulse

Saltatory conduction is the propagation of action potential along myleinated axon from node to node. The "local circuits" explain how the action potential (AP) is transmitted along the neuron. Basically an action potential at a point in the axon, develops

a local circuit because, the influx of sodium ions at that point makes that particular point positively charged. However, regions around that point are still negatively charged (because they are still in the "resting potential formation"). The sodium ions at the point of AP are then attracted to these negatively charged regions, hence setting up a "local circuit" at those regions. This circuit then opens the sodium channels at these points, sodium ions flow in and the whole AP circle continues, hence the AP moves along the axon.

17.4 Synapse

There is no cytoplasmic connection between successive neurons, however, impulses are transmitted and this transmission occur at synapse. **Synapses** are microscopic gap between successive neurons. These gaps are between axon terminal of one neuron and dendrites of another neuron. (Fig.17.9)

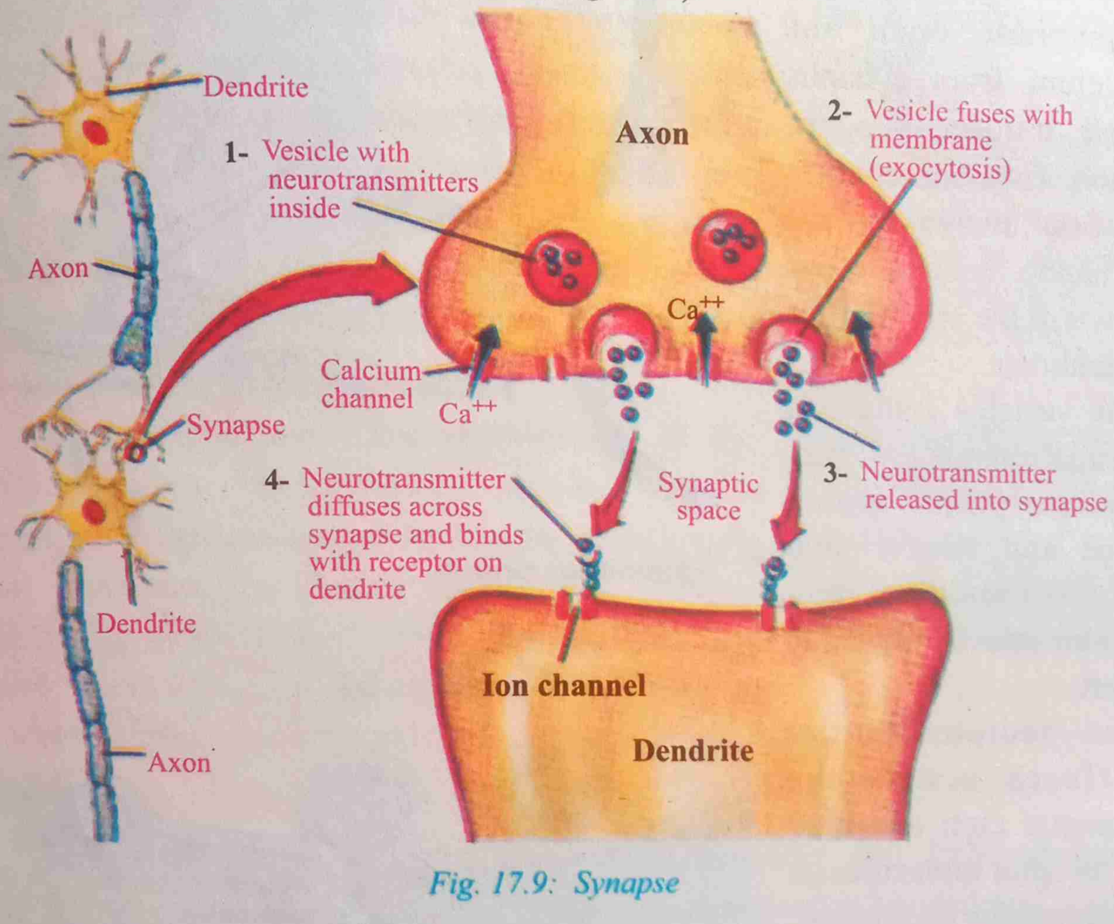


Fig. 17.9: Synapse

A single neuron may form synapses with many incoming fibres of different neurons. The gaps between successive neurons are cleave-shaped thus called **synaptic cleft.** A neuron carries information (impulse towards a synaptic cleft known as **transmitting neuron** or **presynaptic neuron** while a neuron which gets the impulse from synaptic cleft, is called **post synaptic neuron** or **receiving neuron**. The axon

terminals of each presynaptic neuron have expended endings called **knobs** which contain many spherical sacs, known as **synaptic vesicles**. Each vesicle contain as many as 10,000 molecules of chemical messengers, the **neurotransmitter substance**. The dendrite of post synaptic neuron lacks these vesicles. The transfer of impulse across the synapse is called **synaptic transmission.**

Steps of Mechanism of Synaptic Transmission

> **Extra Information**
>
> There are 100 known types of neurotransmitters.

1. When action potential reaches the axon terminal, it is received by synaptic knob. The calcium channels, present in the presynaptic membrane open and calcium from synaptic cleft transfer into the knob. Thus Ca^{++} concentration increases, the synaptic vesicles move towards the pre-synaptic membrane.
2. The vesicles containing neurotransmitter fuse with presynaptic membrane and release their neurotransmitters molecules into the synaptic cleft.
3. The neurotransmitter diffuses across the synaptic cleft and bind to receptor molecules on postsynaptic membrane.
4. The receptor of post synaptic membrane, opens some channels and allow sodium ions to diffuse across the

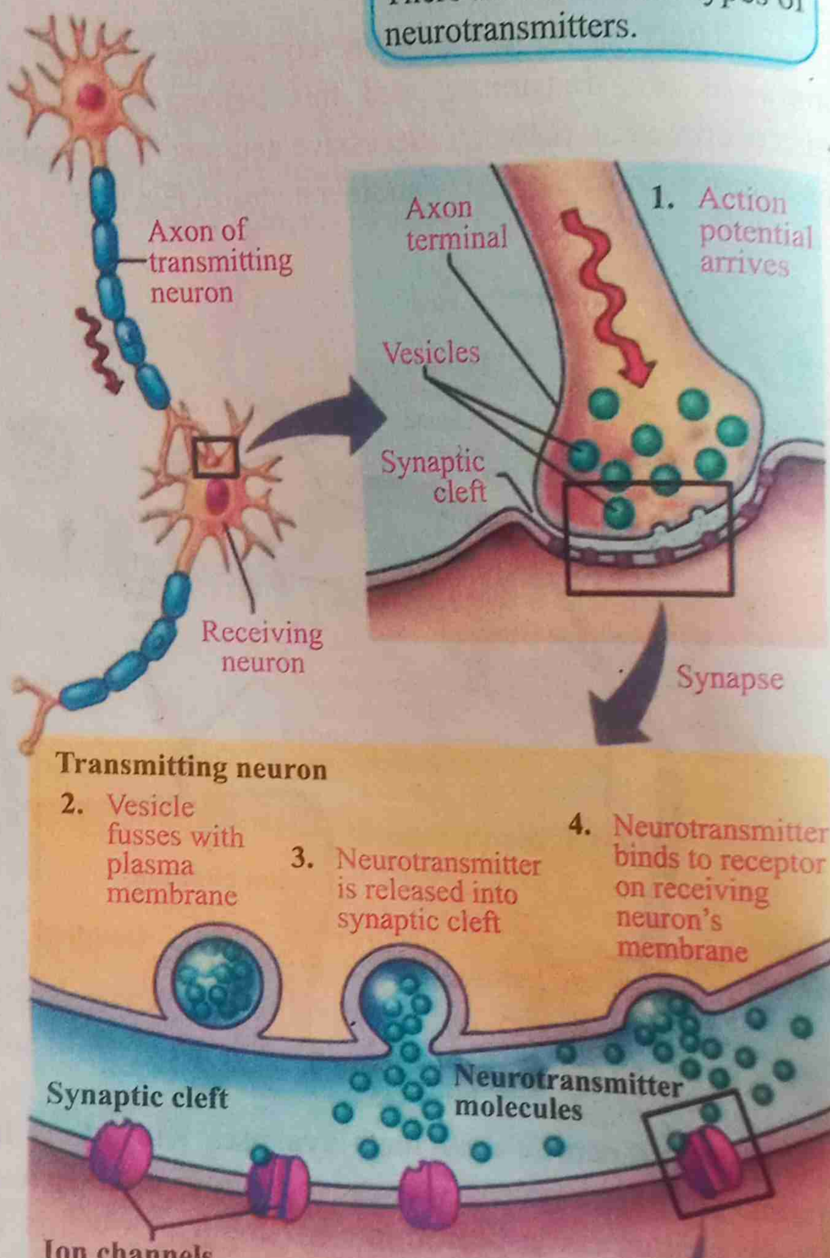


Fig. 17.10: Steps of Synaptic Transmission

postsynaptic membrane. As a result post synaptic membrane depolarizes *i.e.* (inside + outside -) and action potential is generated. Since this depolarization brings the membrane potential towards threshold level, it is called **Excitatory postsynaptic pot-ential (EPSP).**

5. After the activation of post synaptic membrane, the neurotransmitters are immediately broken down by enzymes (like acetylcholinesterase for acetylcholine and monoamine oxidases for adrenaline). (Fig.17.10)

17.4.1 Classification of Neurotransmitters

There are two major classes of neurotransmitters.

1. Excitatory Neurotransmitters

These initiate nerve impulses, cause increased membrane permeability to sodium ions. They may be **acetylcholine** for peripheral nervous system, **biogenic amine** (derived from amino acids) for central nervous system. Their types are **epinephrine** and **nor epinephrine** for heart beat rate during stress; **serotonin** and **dopamine** affect mood, sleep, attention and learning. All of these function like hormones.

2. Inhibitory Neurotransmitter

This decrease membrane permeability to Na^+ ions, which result to raise threshold of stimulus. Thus the nerve impulse does not trigger or lessens, to adjoining neuron. Examples are glycine amino acid, gamma-amino-butyric acid (GABA), while the endorphin are peptides, decreases pain reception and act both as neurotransmitters and hormones.

Interesting Information

There are two types of synapses.

1. **Electrical synapses**, which are rapid and synaptic cleft is only 0.2 nm thick.
2. **Chemical synapses**, in which gap is 20 nm. Thus transfer of impulses occurs by neurotransmitters (Chemicals).

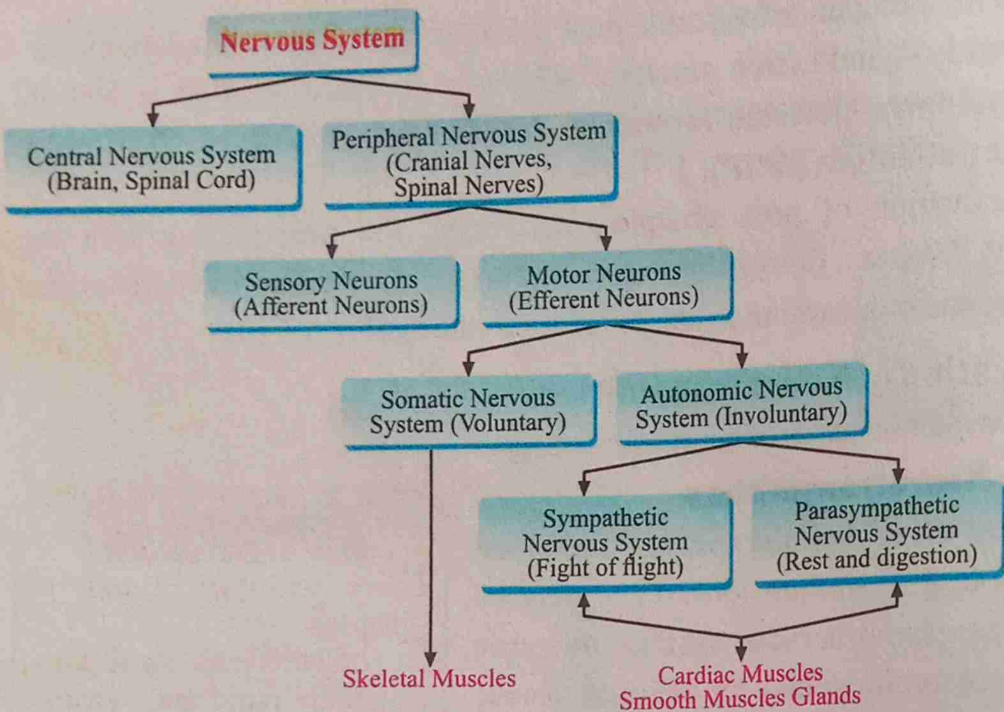
Extra Information

Coelenterates and echinoderms possess diffused nervous system.

17.5 Human Nervous System

Human and most animals (except coelenterates and Echinoderms) have centralized nervous system. Human nervous system is most advanced and also possess some unique features, *i.e.* enable us to convey our complex ideas, information and messages in the form of language, make and use various tools, preserve information (in written and video), great learning, memory storage capacities, *etc.*

Human nervous systems consist of two primary divisions, the central nervous system (CNS) and peripheral nervous system (PNS). (Flow chart 1)



Flow Chart.1: Classification of Human Nervous System

17.5.1 Architecture of Brain and Spinal Cord and their functions

Central Nervous System of Human (CNS)

It consists of brain and spinal cord, act as coordinating centre, these lies in the skull (Brain) and above the vertebral column (spinal cord) *i.e.* in midline of the body.

CNS is hollow and fluid filled. The brain has four cavities called **ventricles** while the cavity of spinal cord is known as **central canal.** The fluid in these cavities named as **cerebrospinal fluid (CSF)** (similar to blood plasma) act as cushion and bathes the neurons of CNS.

Protection of Central Nervous system

The brain is protected by bony cranium of skull while spinal cord is protected by vertebrae of vertebral column. Both brain and spinal cord are also covered by three membranes, collectively known as **meninges (singular; meninx)**, the outer hard **Dura matter** (next to cranium), inner **pia matter,** next to brain and spinal cord and middle **arachnoid matter.** The cerebrospinal fluid is present between the piamatter and arachnoid matter.

Interesting Information

Cerebrum is the largest part of brain and contains highest number of neurons than any other part of brain.

According to "Roger Spray"

Both cerebral hemisphere of cerebrum superficially same but right and left portion function so differently that we could almost say we have two brain in one. Left cerebrum house our language centre, logic mathematical abilities while the right hemisphere imagination, spatial perception, artistic and emotional abilities.

Brain

The brain of human can be divided into forebrain, mid brain and hind brain. (Fig.17.11)

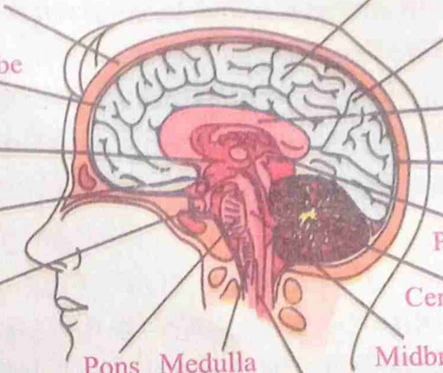


Fig. 17.11: C.S. of Brain of Man

Fore Brain

Forebrain has two sub-divisions; **telencephalon** (cerebrum) and **diencephalon** (thalamus and limbic system). The **cerebrum** of human is largest among all other animals (more than half of the brain). It is divided into two cerebral hemispheres, which are connected together by a band of axons known as **corpus-callosum**. It carries memory available on one side of the brain to the other side. Cerebrum contains four lobes, frontal, parietal, temporal and occipital lobe. The left cerebral hemis-phere controls the right side of the body while right cerebral hemisphere controls left side of the body. Functionally, cerebrum consist of **sensory area**, (receive impulses from receptors), **motor area** (give responses) and **associated area** (interprets or analyses the incoming information) cerebrum act as control centre for sight, smell, taste, speech and hearing. It also controls voluntary movements, thinking, learning, conscious sensations, judgment, reasoning, decision-making, dreams, emotional feeling, intelligence, analysis and interpretation of memory.

> **Extra Information**
>
> There are convolutions (groove) called gyri which are seen on outer part of cerebrum (cerebral cortex). The deep grooves are called fissure while shallow grooves are called sulcus. These grooves greatly increase the surface area of cerebrum. A longitudinal fissure is present between two parts of cerebrum.

Although the motor sensory and associated areas are located in all parts of cerebrum, however motor areas are more abundant in frontal lobe. The associated areas are most occupy the anterior of frontal lobe and wide spread in lateral portion of parietal, temporal and occipital lobes.

Diencephalon (Thalamus and limbic system): **Thalamus** lies below the cerebrum, act as relay centre and carries sensory impulse to the cerebrum and limbic system. Thalamus receives all sensory impulses (except sense of smell).

Limbic System

This system is located in an arc just under cerebrum. The limbic system consists of hypothalamus, amygdala, hippocampus and some part of cerebrum.

Hypothalamus located on the ventral side of thalamus. It is both nervous and endocrine centre *i.e.* link between nervous and endocrine centre.

The function of hypothalamus is to maintain homeostasis and contains centres for regulating body temperature, water balance, menstrual cycle, blood pressure, sleep wake cycle, hunger, sexual response and fight or flight.

Amygdalae are two almond shape masses of neurons on either side of the thalamus. It produces sensation of pleasure, sexual arousal when stimulated, punishment, love, hate, fear and rage.

Hippocampus consists of two horns that curves back from the amygdala and play important role in the formation of long term and short term memory, thus required for learning.

Mid Brain

In human this portion of brain is reduced. It contains auditory relay centre and centre that control reflex movement of eyes also contains auditory reflex centre. Mid brain contains reticular formation, which is a relay centre connecting fore brain with hind brain and is very important in screening the input information before they reach higher brain centres. (Fig.17.12)

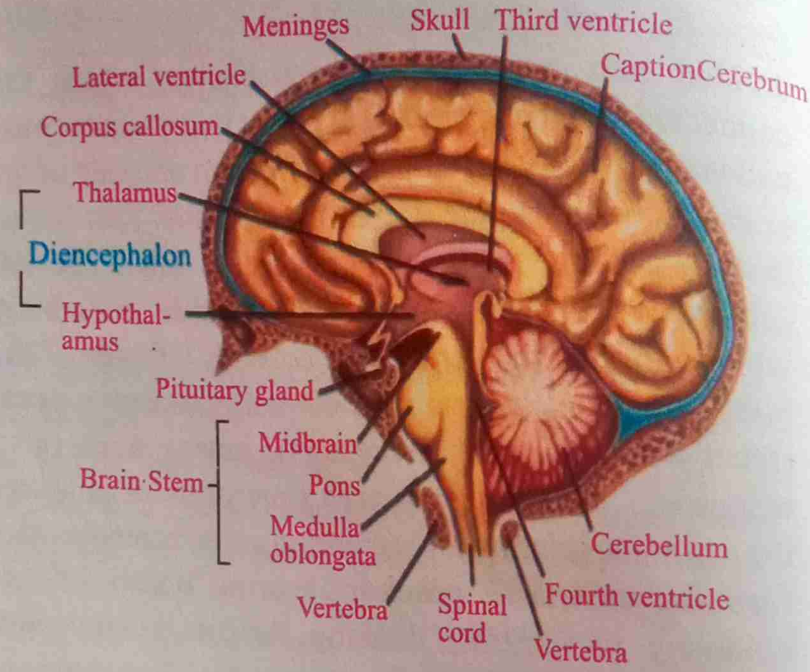


Fig.17.12: Brain Stem

Hind Brain

Hind brain includes the **pons, cerebellum** and **medulla**.

Pons is a group of neuron, located above the medulla; act as a bridge between cerebellum, medulla and cerebrum.

It is involved in rate and pattern of breathing, sleep and wakefulness.

Cerebellum is second largest part of the brain, bulb or leaf like in shape. It coordinates body movements and maintains body position *i.e.* equilibrium. The cerebellum guides, smooth and accurate motions and maintains body position. It also involves in the learning and memory storage for behavior. It is best developed in bird, which engages them in complex activity of flight.

Medulla is last part of brain but in evolutionary point of view, it developed first. It controls several automatic functions, such as heart beat rate, blood pressure, breathing and swallowing.

The mid brain, together with pons and medulla know as **brain stem**, which support the life.

Ventricles of Brain

Human brain possesses four ventricles or cavities, which are filled with cerebrospinal fluid. The first and second ventricles are present between limbic system and cerebrum known as **lateral ventricles**. Another ventricle is present between limbic system and thalamus called **third ventricle** while **fourth ventricle** is present in medulla. There is a tube between third and fourth ventricle known as **iter or cerebral aqueduct**, while an opening between lateral ventricles and third ventricle is called intra **ventricular foramen**. (Fig.17.13)

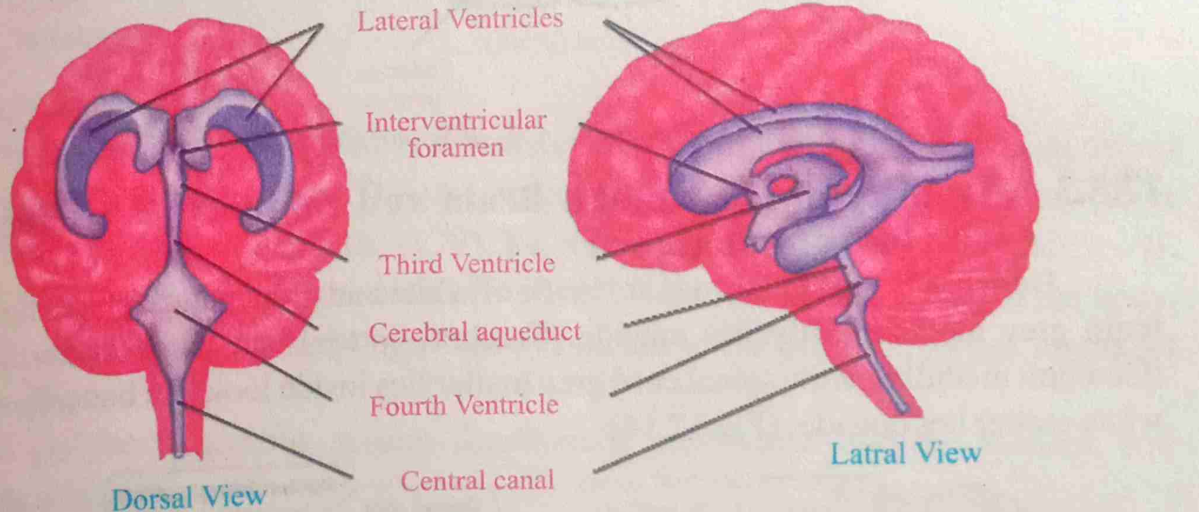


Fig. 17.13: Ventricles of the Brain

17.5.2 Spinal Cord

Medulla narrows down into the spinal cord. It is an elongated, hollow fluid filled and cylindrical structure, extends from the **foramen magnum** (a hole in the bottom of skull) lying in the neural canal of vertebral column (up to 3rd lumbar vertebrae). In a cross section of spinal cord exhibits inner butterfly shaped **grey matter** while peripheral **white matter**. There is a tiny central canal in the centre of grey matter, filled with CSF around the **central canal** is a single layer of cells called **ependymal layer**.

> **Interesting Information**
>
> Local anaesthesia is given at fourth lumbar, so as to protect the spinal cord.

The grey matter consists of non-myelinated portion *i.e.* mostly cell bodies of

neuron while white matter is composed of myelinated nerve fibres *i.e.* mostly axons. Spinal cord controls reflexes below the neck region. It also conducts impulses to and from the different part of the bodies and brain. Thus helps in better function of brain. (Fig.17.14)

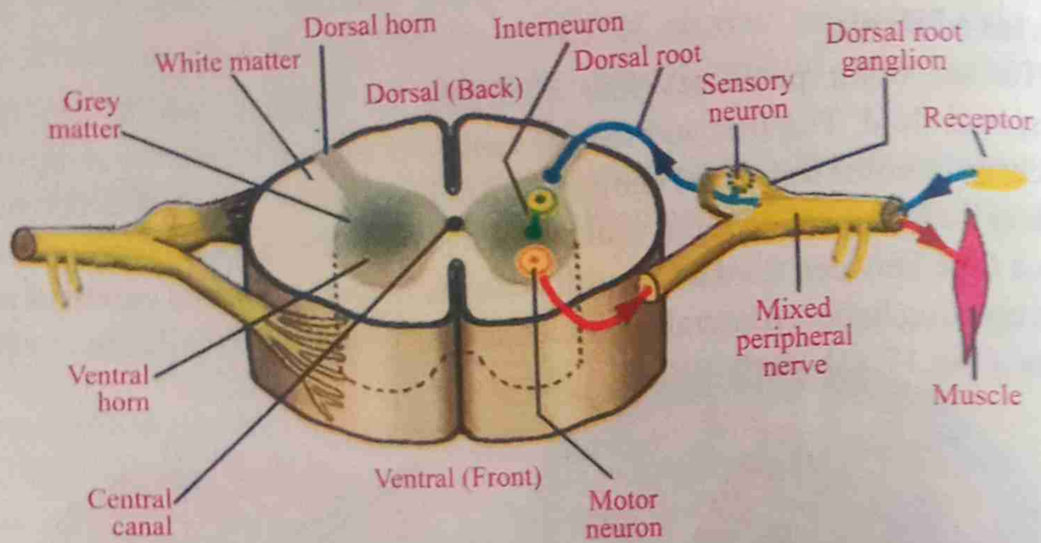


Fig. 17.14: C.S. of Spinal Cord

17.5.3 Architecture of Human Brain and compare its sectional view with that of spinal cord

Both brain and spinal cord are made of white and grey matter. The difference is in brain grey matter mostly lies outside (Cerebral cortex) and white matter lies inside (Cerebral medulla) while spinal cord grey matter lies inside look like butterfly shape and white matter lies outside. (Fig.17.14)

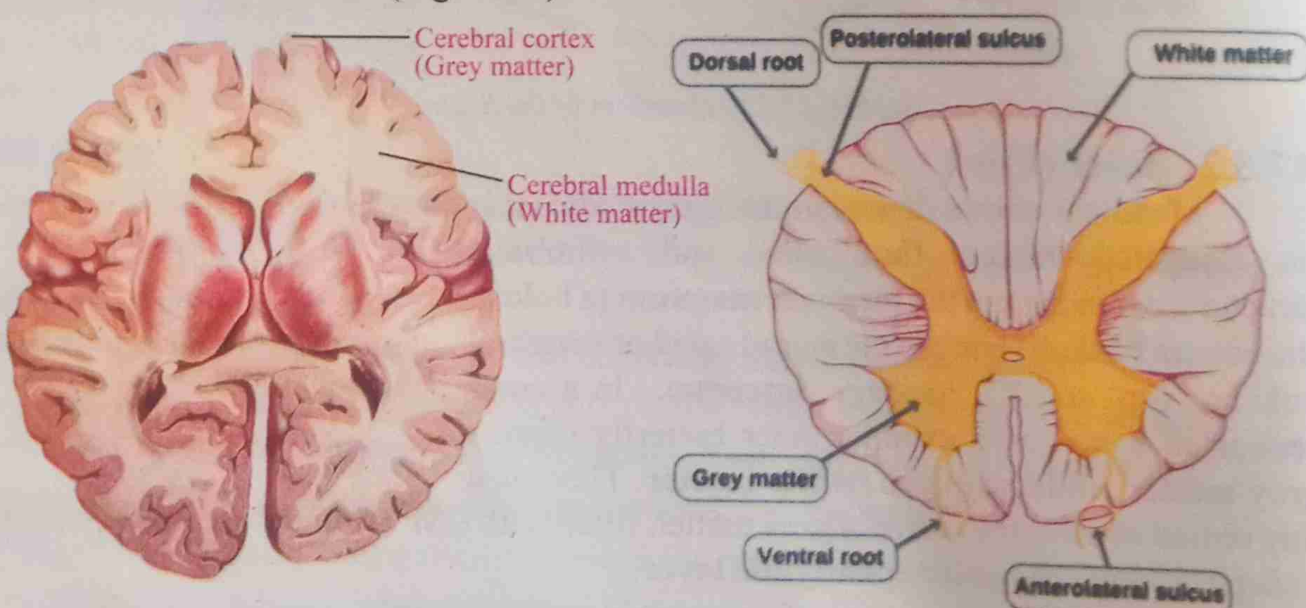


Fig. 17.15: Cross Section view of Brain and Spinal Cord

17.5.4 Peripheral Nervous System

It is the system of nerves and ganglia. The **nerves** are cables of bundles of nerve fibres (axon and dendron fibres) while ganglion is the concentration of cell bodies of neurons with in peripheral nervous system. Nerves may be **sensory nerves** (contains sensory neurons), **Motor nerves** (contain motor neurons) and **mixed nerves** (contains both sensory and motor nerves). There are two types of nerves on the basis of their origin *i.e.* spinal nerves and cranial nerves.

Spinal Nerves

In human thirty-one pairs spinal nerves, all are mixed. Each serves those regions of the body where it is located, Cervical, 8; Thoracic, 12; Lumber, 05; sacral, 05; coccygeal, 01. Each nerve has a dorsal root, contains sensory fibres and ventral root contains motor fibres. Both of these roots join just before a spinal nerve leave the vertebral column.

Cranial Nerves

These nerves are also called **cerebral nerves**. There are 12 pairs of cranial nerves arising from or lead to the brain. The cerebral nerves functionally may be sensory (three pair I, II VIII), motor (five pairs, III, IV, VI, XI, XII) and mixed in nature (four pair V, VII, IX and X). These are mostly concerned with head, neck and facial regions of the body, only 10^{th} cranial nerves, named **vagus** have branches to the pharynx, larynx and most internal organs.

The peripheral nervous system functionally subdivided into the somatic and autonomic nervous system.

Somatic Nervous System (SNS)

This subdivision controls voluntary movements which are consciously controlled, involving skeletal muscles except reflex action of skeletal muscles.

Autonomic Nervous System (ANS)

This subdivision controls involuntary responses (automatic and subconscious), consists of both sensory neurons and motor neurons that runs between central nervous system and many viscera like lungs, heart and glands. Autonomic nervous system also controls the contraction of cardiac and smooth muscles.

The motor neurons of autonomic nervous system are divided into sympathetic nervous system and parasympathetic nervous. The differences between these two system are explained in the Table 17.1. (Fig.17.16)

Table 17.1: Differences between Sympathetic and Parasympathetic Nervous System

Sympathetic Nervous System	Parasympathetic Nervous System
• It prepares the body for emergency situations and associated with "flight and flight". Increase metabolism to avoid danger. • Accelerates the heart beat from set point, rise BP. • Dilates Pupils • Inhibits digestion of food • Most preganglionic fibre (nerves) arise from the middle portion of the spinal cord and almost immediately terminate in ganglia that lie near the spinal cord. • Preganglionic fibres are short and postganglionic long.	• It promotes all internal responses which are concerned with the rest situation, and maintain body homeostasis, *i.e.* returns body functions to normal position. • Retards heart beat that is maintain at set point and lowering of BP. • Contracts Pupils. • Increases digestion of food. • A few cranial nerves, including the vagus nerve, together with fibres that arise from the sacral (bottom) portion of the spinal cord. • Preganglionic fibres are long and postganglionic short.

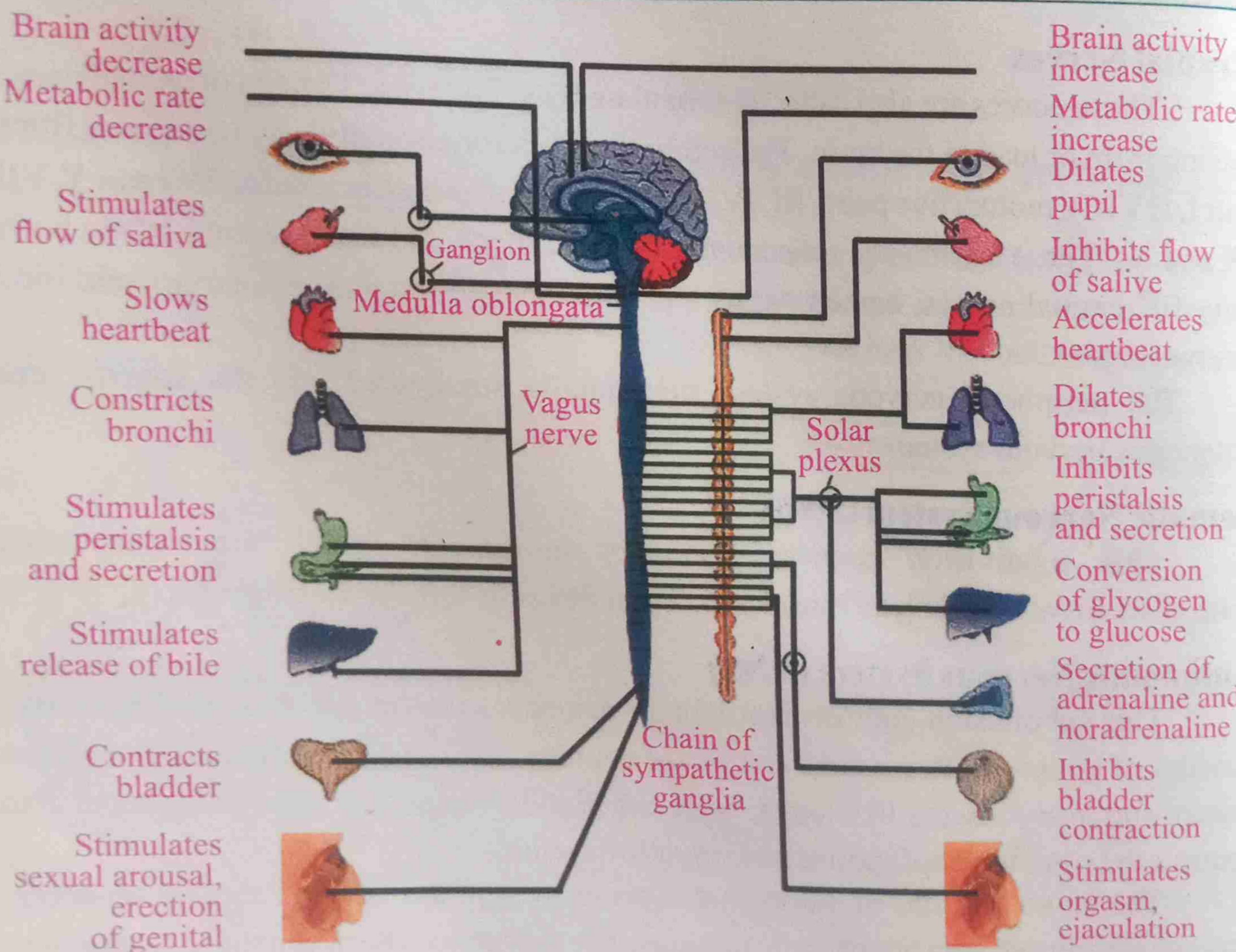


Fig. 17.16: Parasympathetic and Sympathetic Nervous System

17.5.5 Structure and Functioning of Receptors of Smell, Taste, Touch and Pain

1) Smell or Olfactory Receptors

The receptors, which are stimulated by chemicals are called smell or olfactory receptors. In human it is not as much developed or important as vision and hearing. Although in most predators sense of smell is highly developed and important to detect preys. These receptors are located in the upper part of the nasal cavity, which are neurons. The neurons are surrounded by ciliated columnar epithelial cells. Chemicals that stimulate the olfactory receptors enter the nasal cavity as gases, which dissolve in watery fluids that surround the cilia before they can be detected. The axons of neurons carry the smell impulses to the olfactory bulb of fore brain for appropriate responses. (Fig.17.17)

> **Interesting Information**
>
> There are about 1,000 different types of receptor protein on receptor neurons, each is sensitive to different odors.

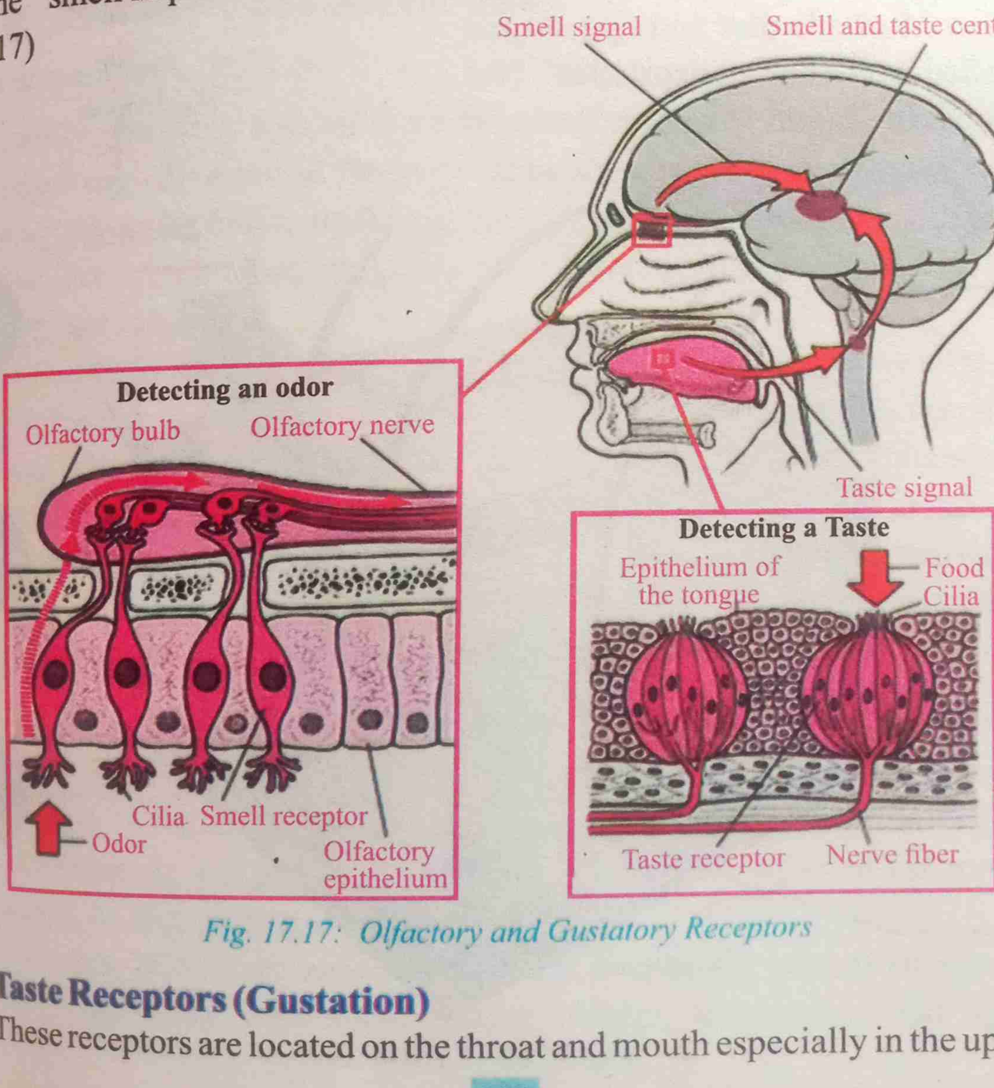


Fig. 17.17: Olfactory and Gustatory Receptors

2) Taste Receptors (Gustation)

These receptors are located on the throat and mouth especially in the upper surface

of tongue as many raised structure called **papillae or taste buds**. Each taste bud has a pore through which fluid in the mouth contact the surface of receptor cells.

There are thousands of taste buds which perceived tastes, all are combination of four primary sensations; **sweet** (elicited by sucrose, glucose and other simple sugars), **sour** (acids), **salty** (NaCl and other salts) and **bitter** (alkaloids and other potentially toxic plant substances). (Fig.17.18)

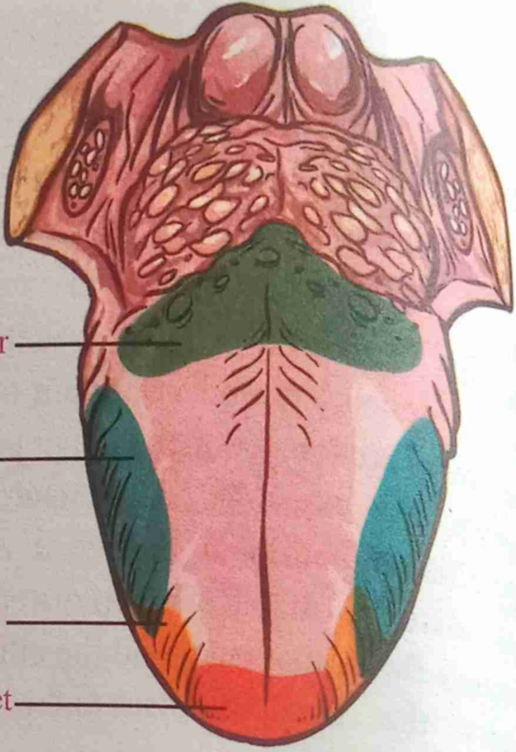


Fig. 17.18: Four Receptor on the Tongue

3) Touch (Tactile Receptor)

There are two touch receptors (also called **mechanoreceptors**) disc-shaped dendrite endings called **Merkel's disc** and egg shaped receptors called **Meissner's corpuscles'**. (the word corpuscle mean "Little body"). (Fig.17.19)

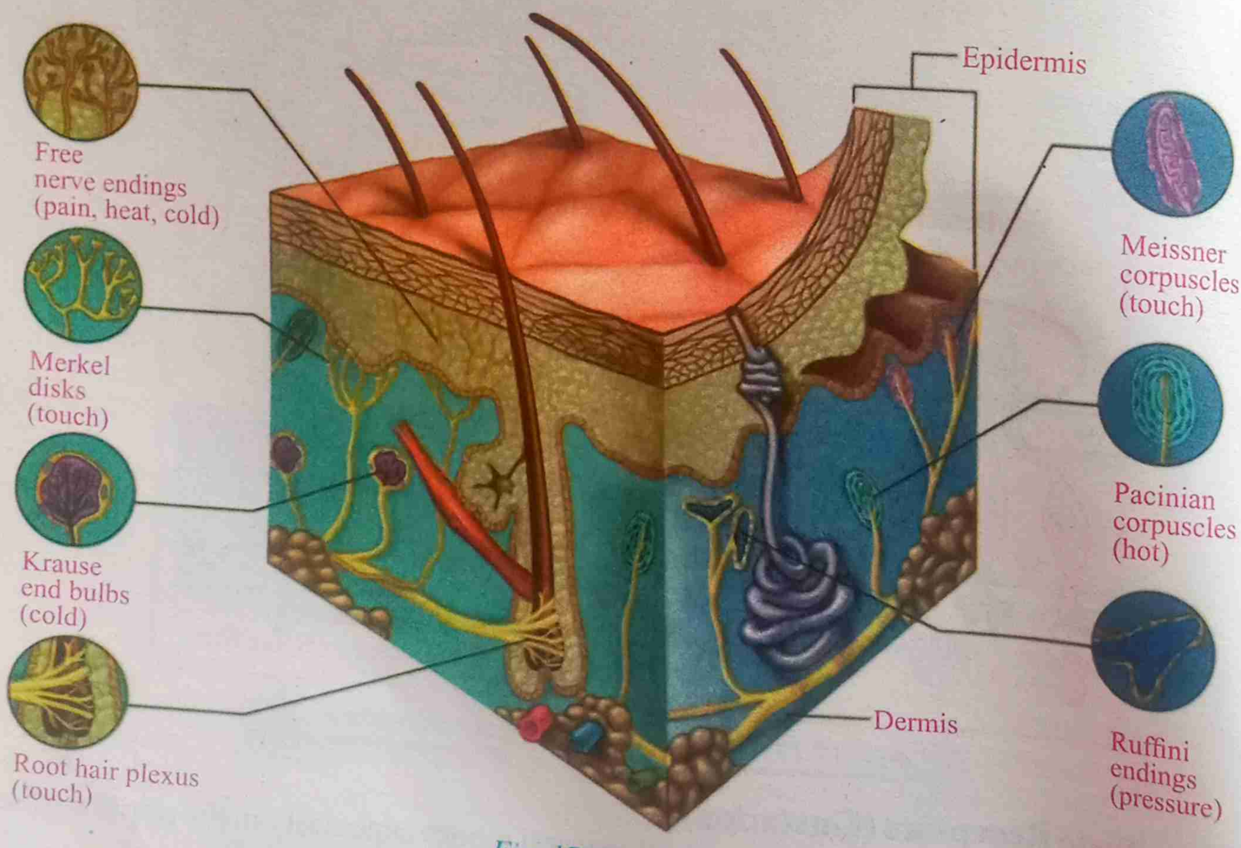


Fig. 17.19: T.S Skin

Both these receptors are widely distributed in the skin but are most numerous in the hands (finger tips), feet, and eyelids, tip of the tongue, lips, nipples, clitoris and tip of the penis. In addition, free nerve endings wrap around the roots of hairs, detect stimulus like wind or an insects that moves body hair.

Pressure receptors called **pacinian corpuscles** are placed deeper with in skin.

1) Pain Receptors (Nociceptors)

There are three types of pain receptors, *i.e.* **cutaneous** (skin), **somatic** (Joints and bones), and **visceral** (all body organs except brain). These receptors are naked dendrites that respond to chemicals released from injured tissues or excess stimuli of pressure and heat.

2) Thermorceptors

Which are encapsulated nerve endings located in the dermis of skin (for hot **Ruffini ending** and for cold **Krause end bulbs**).

17.6 Effects of Drugs on Nervous Coordination

Broadly speaking, **a drug** is a substance introduced into the body to provoke a specific physiological response. Some drugs help a person cope with illness or emotional stress. Other act on the brain, artificially fanning pleasure associated with sex and other self-grafting behaviors. Many drugs are habit-forming. **Habituation** and tolerance are sign of **drug addiction**.

A **narcotic** is a group of substances, bind to certain pain killing sites in the brain thus stop the perception of brain. Their constant use blocks the production of endorphin (natural pain killer hormone secreted from anterior pituitary gland). Thus narcotic acts as an agent which interacts with the normal nervous activity.

The **side effect of narcotics** is change in mood, drowsiness, nausea, vomiting, **euphoria** (an exaggerated feeling of wellbeing), *etc*. Some common narcotic drugs are discussed here.